IES Newsletter

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Humans, Nitrogen and Rivers

Nitrogen levels in the world's rivers are rising — some to potentially dangerous levels — and a study by Institute of Ecosystem Studies scientists indicates a direct correlation with increasing human population. This study was reported recently in the scientific journal *Nature* (4 April 1991), in a paper by research assistant Benjamin L. Peierls with co-authors Drs. Jonathan J. Cole, Nina F. Caraco and Michael L. Pace.

Nitrogen (its chemical symbol is N) is an element that is necessary for life. Nitrogen gas, N_2, makes up nearly 80% of our atmosphere and combines naturally with oxygen or hydrogen to make other chemical compounds. Plants and microorganisms absorb certain of these compounds from the environment and convert them into nucleic acids, amino acids and proteins. Animals obtain their nitrogen from the plant-produced amino acids, which are used to build protein.

Some nitrogen compounds, on the other hand, can have detrimental effects. For example, nitric acid — one of the contributing factors to acid rain — is formed in the atmosphere when emissions from anthropogenic activities, such as the burning of fossil fuels, combine with water vapor. Also, when there is a heavy input of nitrogen to an aquatic or marine ecosystem, especially to a system with little exchange with open waters, eutrophication* is often a result.

The study by Institute ecologists had its roots in an Environmental Defense Fund report issued three years ago. That report suggested that approximately 25% of the nitrogen in the waters of Chesapeake Bay — a body of water nearly surrounded by land and bordered by Maryland and Virginia — came from rainwater. After learning of these data, the Environmental Protection Agency (EPA) wanted to investigate similar coastal systems to see if the reported findings were representative, and asked scientists at the University of Rhode Island to coordinate a wider study. Those scientists, in turn, asked Drs. Cole, Caraco and Pace and Mr. Peierls to report on nitrogen levels in the Hudson River and the New York Bight (the triangle-shaped piece of coastal water into which the Hudson River drains; its apex is at New York Harbor and it extends along a 200 meter-deep (approximately 660 feet) line from Montauk Point, Long Island to Cape May, New Jersey). Other groups were responsible for other areas. Dr. Cole and his colleagues gathered all available data

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**Eutrophication of a body of water occurs when a build-up of nutrients, for example nitrogen or phosphorus, leads to so much algal growth that the normal feeding of fish and other aquatic animals cannot keep the "bloom" under control. Bacterial decomposition of the massive amounts of dead algae depletes the oxygen in the water, potentially resulting in death of fish and other aquatic animals.*

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continued on page 2

Four Institute ecologists collaborated on the survey of nitrogen levels in the world's major rivers. Left to right: Dr. Nina Caraco, Benjamin Peierls, Dr. Michael Pace and Dr. Jonathan Cole.

Director's Note

Scientists and educators at the Institute of Ecosystem Studies work at field sites, and/or with collaborators, in 30 states, the District of Columbia and Puerto Rico, and in 15 other nations around the world. In some of these areas, the research is related directly to that being done concurrently in our laboratories and offices in Millbrook; examples include studies of the global transport of atmospheric pollutants (see page 3), and the expansion and dissemination of the Eco-Inquiry curriculum. In other cases, investigations at distant sites are independent of other IES work. Results of the studies are published and thereby become available to other scientists and educators as well as to the general public.

Institute scientists and educators make use of published data as well. As described in the cover story, four Institute ecologists spent six months reviewing scientific literature to develop a model of nitrogen levels in the world's major rivers. Their conclusions, which appeared recently in *Nature*, will be of interest and relevance to environmental managers around the world.

The IES Newsletter is published by the Institute of Ecosystem Studies at the Mary Flagler Cary Arboretum. Located in Millbrook, New York, the Institute is a division of The New York Botanical Garden. All newsletter correspondence should be addressed to the Editor.

Gene E. Likens, Director
Joseph S. Warner, Administrator
Alan R. Berkowitz, Head of Education

Editor: Jill Cadwallader
Printing: Central Press

INSTITUTE OF ECOSYSTEM STUDIES
The New York Botanical Garden
Mary Flagler Cary Arboretum
Box AB
Millbrook, NY 12545
(914) 677-5343

Nitrogen, *from page 1*

and put together a nitrogen "budget" for the New York Bight, of which the Hudson River is a major component. It was concluded that rainwater was an important source of nitrogen here as well.

The world's rivers

The work made the IES team curious about nitrogen budgets of other major rivers of the world. In what ways besides acid rain might human activities affect nitrogen input? For six months the four scientists met as a study group and reviewed water chemistry and population data on 42 of the world's largest rivers that drain into ocean waters . . . and, incidentally, are responsible for about 37% of the total freshwater input to the ocean. Long-term data for both the Mississippi and Rhine rivers helped to substantiate the findings. The results were clear. Rivers with the highest levels of nitrate — a dissolved compound of nitrogen and oxygen — were those with the highest human populations in their watersheds; rivers with low nitrate levels were low in population. The best predictor of river nitrogen concentration and export to the world's oceans, then, was human population density.

In analyzing the types of human activities that lead to the input of nitrogen to rivers, the scientists calculated that sewage alone could account for high nitrate levels. This means than even the most basic human activity is enough to explain the correlation. However, other human influences, including agriculture and deforestation as well as the atmospheric pollution and deposition mentioned earlier, also affect the amount of nitrogen that enters the waterways.

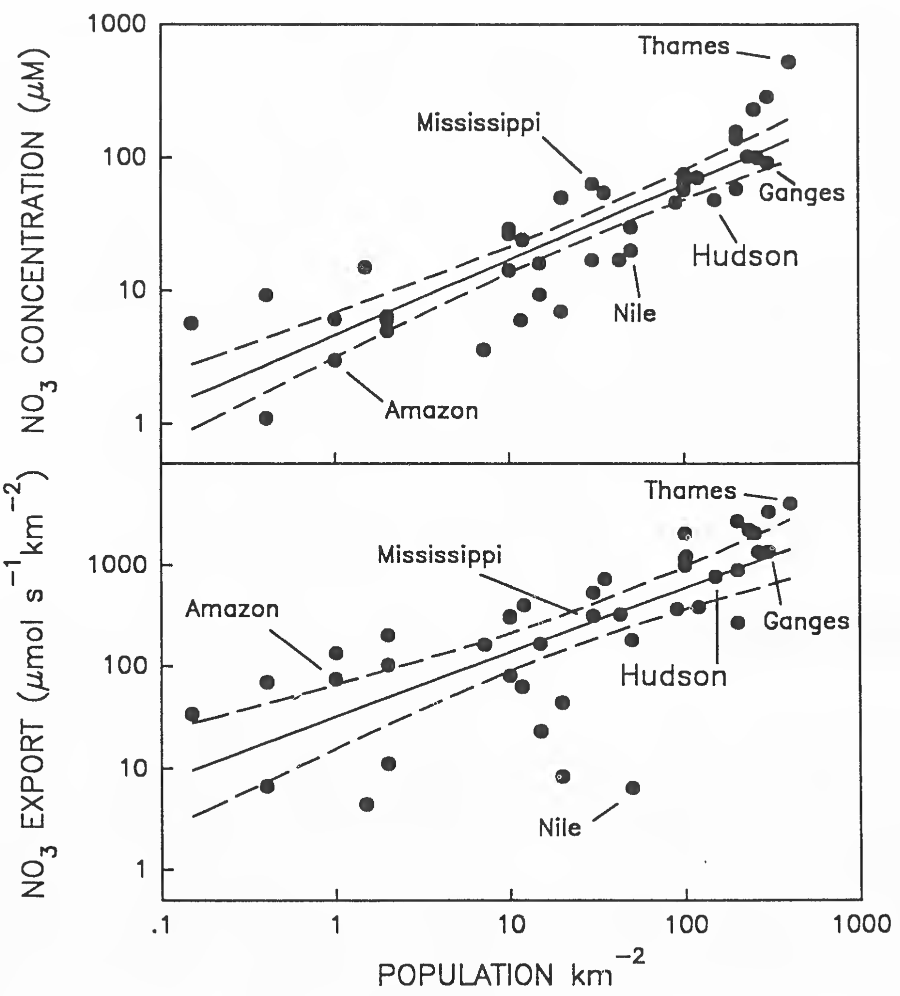
Consequences of higher nitrate levels

Increased nitrate in marine and freshwater ecosystems can have consequences ranging from the unpleasant to the dangerous. With eutrophication of coastal areas, the once-pristine shoreline environment is no longer appealing as a recreation area. More serious, nitrate in drinking water poses a health threat, specifically a disease called "methemoglobinemia." Nitrate that enters the body in water or food changes to nitrite in the gastrointestinal tract. Nitrite passes from there into the bloodstream where it reacts with hemoglobin, interfering with the normal transport of oxygen. Methemoglobinemia can be serious in infants and some animals, so the World Health Organization and the EPA have set rigorous standards for nitrate contamination in groundwater.

What can be done to reduce nitrogen levels in the waters of the world? An ideal solution, according to Dr. Cole, would be slower growth of the global human population, although the situation also would be improved if fewer people moved into major watersheds and coastal areas. Another approach would be the actual removal of nitrogen from a system, and at some high-technology sewage treatment plants experimental techniques are being tested in which nitrogen under anoxic conditions is turned microbiologically into nitrous oxide or N_2, both gasses. This procedure reduces nitrogen levels by only 50%, however, and since nitrous oxide is a greenhouse gas this partial "cure" for one problem could aggravate another, global warming.

And how does the work by Institute ecologists help solve the problem? Their findings provide a model for study of major river systems. With the publication of the paper in *Nature*, attention has been drawn to the potentially undesirable consequences of projected population growth on the world's waters. Armed with this evidence, environmental managers and policy makers can work for long-term solutions.

NITROGEN CONCENTRATION AND EXPORT IN THE WORLD'S MAJOR RIVERS



The top figure shows the average annual nitrate concentration in 42 rivers of the world, including the Hudson River, plotted against the corresponding human population density in the rivers' watersheds. The lower figure details nitrate export, again plotted against the human population density, and its data points reflect the runoff rates of the rivers. ("Runoff" is the discharge of water from land, per unit area.) The Nile River, for example, while having a relatively high concentration of N, has a low runoff rate and therefore exports relatively low amounts of nitrate. The Hudson River has both a high concentration of N and a high level of nitrate export.
Note: Both scales increase by factors of 10 along the axes.

The growth of seedlings and saplings is affected by the amount of available resources — sunlight, water and soil nitrogen — reaching the forest floor. Of these three resources, the most challenging to measure accurately is light because the sun is constantly changing its position relative to the leaves in the forest canopy. Since the pattern of light on the forest floor is influenced by the canopy, the amount of light that reaches the understory also changes. Now, with the help of two of the Institute's staff, IES plant ecologist Dr. Charles Canham has developed an ingenious system to measure the amount of sunlight that passes through the forest canopy.

A camera whose fish-eye lens has a 180° field of view is housed in a box mounted on top of a hydraulic lift. This portable device is set up on the forest floor, and, with compressed carbon dioxide powering the lift, the camera is raised and positioned directly under the foliage of an individual tree. The pointed roof of the housing, which has protected the delicate camera from branches and leaves on the way up, opens, and the scientist on the ground below (in this case Adrien Finzi, a graduate student of Dr. Canham's at the University of Connecticut) uses a long cable release to take a photograph up into the canopy. More photographs are taken at meter intervals as the camera is lowered. With this technique, the camera becomes a sophisticated "light meter," recording the condition of the canopy.

But how does a set of photographs that captures the canopy over a short interval on one day tell Dr. Canham about sunlight patterns on the forest floor over an extended period? Interpretation of the photographic data is accomplished by a specially-written computer program that calculates the sun's position over the tree in the photograph at two-minute intervals for each day of the entire growing season. Analysis of the computer results, then, compared with the growth patterns of seedlings and saplings on the forest floor, helps Dr. Canham determine how some plants influence light levels on the forest floor and how other plants respond to those levels.


DIANE BURBANK

Dr. Canham enlisted the help of several of the Institute's employees to develop this complicated but effective technique. Last summer, mechanic Jim Boice adapted a hydraulic system for use in the forest, his main challenge being the development of four independently adjustable legs at the base of the system to allow for leveling on the uneven forest floor. This year Mr. Boice worked with Dr. Canham to come up with a plan for the camera housing, and then he designed and built it. For the second part of the work, the computer analysis, special software had to be created. Here, Dr. Canham worked with high school student Geoff Lloyd, and over several summers Mr. Lloyd developed the necessary computer programs. Data collected and analyzed as a result of the pooled talents of these individuals will be used in conjunction with data on availability of water and soil nitrogen to increase scientific understanding of forest dynamics.

This research, funded by the National Science Foundation, is being done in Great Mountain Forest in Norfolk, Connecticut.

IES Notes

. . . Students in the Millbrook, N.Y. school system took it upon themselves over the summer to raise the money needed to support the school's athletic program during the coming year.
In one of a number of fund-raising activities, 12 high school students volunteered a total of 200 hours at the Institute of Ecosystem Studies. In return, the Institute made a donation of $1,000 to the Millbrook Blazer Booster Club. The students worked with Bradley Roeller, manager of display gardens, and his staff. Six spent their time renovating planting beds in the lath house, at right, while the other group removed an overgrown planting of juniper along Lovelace Drive near the Fern Glen.


JILL CADWALLADER

. . . Since 1979, Dr. Gene E. Likens and his colleagues in the Global Precipitation Chemistry Project (GPCP) have been collecting and analyzing precipitation chemistry data at various sites around the world. The purpose of this work is to determine what factors regulate the chemical composition of rain and snow in continental and marine areas remote from industrial and agricultural influences. One of these remote areas is Torres del Paine, in the Andes Mountains of southern Chile, where findings sparked an interest in further ecological studies. In late August, three Chilean scientists visited the Institute to meet with Dr. Likens, IES director, and his GPCP colleagues in order to write a proposal to evaluate the ecological significance of chemical input from the atmosphere to lakes in southern Chile.

Fall Calendar

CONTINUING EDUCATION PROGRAM

The **fall semester** began in mid-September but new classes and workshops are offered in October and November as well, with holiday workshops scheduled from October through December. Register now for these landscape and gardening workshops:

Oct. 19: **Restoring Nature to the Residential Landscape**
Nov. 2: **Practical Tools for Landscape and Open Space Preservation**
Nov. 7: **Fall in Your Garden**

SUNDAY ECOLOGY PROGRAMS

Free public programs are held on the first and third Sunday of each month, except over holiday weekends. Programs begin at 2 p.m. at the Gifford House on Route 44A unless otherwise noted*. Call (914) 677-5359 to confirm the day's topic.

Oct. 20: **How Beavers Change the World**, a walk led by Erik Lilleskov (*Meet at the Greenhouse parking lot, on Rte. 82.)
Nov. 3: **Nature in the City**, an illustrated talk by Richard Pouyat
Nov. 17: **Ecology of the Endangered Marine Otter in Chile**, an illustrated talk by Dr. Richard Ostfeld
Dec. 1: **An Origami "Winter Ecosystem,"** an activity led by Jill Cadwallader

For outdoor programs, wear long pants and sturdy shoes with socks.
In case of inclement weather, call (914) 677-5358 after 1 p.m. to learn the status of the day's program.

IES SEMINARS

The Institute's program of **scientific seminars** features presentations by visiting scientists or Institute staff. Free seminars are held at the Plant Science Building on Fridays at 3:30 p.m.

Oct. 18: **Ecological Genetics of Resistance to Fungal Pathogens in the Common Morning Glory**, by Dr. Ellen Simms, Univ. of Chicago
Oct. 25: **Why Do Populations of Small Mammals Cycle?**, by Dr. Rudy Boonstra, Univ. of Toronto
Nov. 1: **Influence of Plant Chemicals on Insect Predation and Parasitism**, by Dr. Elizabeth Bernays, Univ. of Arizona
Nov. 8: **Plant Defense: General or Specific Response to Insects and Pathogens**, by Dr. Vera Krischik, Institute of Ecosystem Studies
Nov. 15: **Modeling Plant Litter Decomposition from Integrated Enzyme Activities**, by Dr. Robert L. Sinsabaugh, Clarkson University, New York
Nov. 22: **Nitrogen Dynamics in the Riparian Zone of Two Tropical Watersheds**, by Dr. W. H. McDowell, Univ. of New Hampshire
Dec. 6: **Factors Affecting Nutrient Cycling by Microorganisms**, by Dr. David Caron, Woods Hole Oceanographic Institution, Massachusetts

Call (914) 677-5343 to confirm the day's seminar topic.

GREENHOUSE

The IES greenhouse is a year-round tropical plant paradise as well as a site for controlled environmental research. There is no admission fee, but visitors should stop first at the Gifford House for a free permit.

GIFT SHOP

Senior Citizens Days: On Wednesdays senior citizens receive a 10% discount on all purchases (except sale items).
Annual Pre-Holiday Sale: Friday, Saturday and Sunday, December 6, 7 and 8. Members receive a 20% discount on gifts and plants, and a 10% discount on books.

ARBORETUM HOURS
(Winter Hours: October 1 - April 30; closed on public holidays)

The **Arboretum** grounds are open Monday through Saturday, 9 a.m. to 4 p.m.; Sunday 1 - 4 p.m. Internal roads and trails are closed during the deer hunting season.

The **Gift and Plant Shop** is open Tuesday through Saturday 11 a.m. to 4 p.m. and Sunday 1 - 4 p.m. (closed weekdays from 1 - 1:30 p.m.).

All visitors must obtain a free permit at the Gifford House for access to the Arboretum. Permits are available up to one hour before closing time.

MEMBERSHIP

Become a member of the Mary Flagler Cary Arboretum. Benefits include a special member's rate for IES courses and excursions, a 10% discount on purchases from the Gift Shop, a free subscription to the IES NEWSLETTER, and parking privileges and free admission to the Enid A. Haupt Conservatory at The New York Botanical Garden in the Bronx. Individual membership is $30; family membership is $40. For information on memberships, contact Janice Claiborne at (914) 677-5343.

For more information, call (914) 677-5359 weekdays from 8:30 - 4:30.

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